**UCRL-JC-125679 Abs**

# Modeling of Shock Hardening Effects In Copper

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## Abstract

Many experimental studies have investigated the effect of shock pressure on the post-shock mechanical properties of OFHC copper. These studies have shown that significant hardening occurs during shock loading due to dislocation processes and twinning. We have shown that when an appropriate initial value of the Mechanical Threshold Stress (MTS) is specified, the post-shock flow stress of OFE copper is well described by relationships derived independently for unshocked materials [1]. However, in order to simulate, using explicit hydrodynamic computer codes, the temperature and deformation of a shaped charge or EFP liner from high explosive loading, the material model should accurately treat the shock hardening effects during the shock process. We have also shown that it is possible to “reverse engineer” the properties of shocked copper for EFP liners [2,3], however, this process requires several warhead type tests for the calibration process.

In this study we address the evolution of the MTS during shock loading processes and the effect on the subsequent flow stress of the copper. An increased post shock flow stress results in a higher material temperature due to an increase in the plastic work. An increase in temperature leads to thermal softening which reduces the flow stress. These coupled effects will determine if there is melting in a shaped charge jet or a necking instability in an EFP liner. The critical factor is the path followed combined with the “current” temperature, plastic strain, and strain rate. Preliminary studies indicate that in simulations of shock processes with very high resolution zoning, the MTS saturates because of the rate dependence in the evolution law. On going studies are addressing this and other issues with the goal of developing a version of the MTS model that treats shock loading, temperature, strain, and rate effects apriori.

1. W.H. Gourdin and D.H. Lassila, “Deformation Behavior of Pre-Shocked Copper as a Function of Strain Rate and Temperature”, UCRL-JC-106130, presented at APS 1991 Topical Conference on Shock Compression of Condensed Matter, Williamsburg, VA June 17-20, 1991.

2. M.J. Murphy and E.L. Baker, “Using Nonlinear Optimization Methods to Reverse Engineer Liner Material Properties from EFP Tests”, UCRL-JC-117649, presented at 15th International Symposium on Ballistics, Jerusalem, Israel, May 21-24, 1995.

3. M.J. Murphy, "Constitutive Model Parameter Determination from Generic EFP Warhead Tests", J de Physique IV, Colloque C8, Vol 4, 483, (1994).

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract W- 7405-Eng-48.